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Canada Centre for Mineral and Energy Technology
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Mining Research Laboratories
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Canada/NB MDA Project on Mine-shaft Rope Testing; testing of $1\frac{5}{8}$ in., 18×7, NR, T. R., (our rope #8)

L.B. Geller, D. Poffenroth, J.E. Udd, and D. Hutchinson

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MICROMEDIA

CANADA/NB MDA PROJECT ON MINE-SHAFT ROPE TESTING; TESTING OF $1\frac{5}{8}$ in., 18×7, NR, T. R. (OUR ROPE #8)

by

L.B. Geller*, D. Poffenroth†, J.E. Udd**, and D. Hutchinson††

ABSTRACT

In this report the authors analyse the test-results obtained non-destructively on a $1\frac{5}{8}$ in. diameter, 18×7, spin-resistant/non-rotating (NR‡) tail-rope (T.R.). The rope was only examined reel-to-reel as part of CANMET's project to comparatively evaluate the performance of a range of EM wire-rope testers. However, results of previous in-situ testing were also available. This is the first time that a project of this magnitude and diversity has been undertaken.

The rope was tested with the Canadian Magnograph, Rotesco AC, and Rotescograph, with the American LMA-250, and with the German WBK instruments. The maximum estimated strength-loss (LBS) was reported as being negligible by the Rotescograph operator, and 2.9% by the Magnograph operator. The operators of the American and German instruments did not submit LBS estimates.

Within the context of CANMET's present project it was intended to only test ropes that were in a bad, or very bad, condition. In this context the condition of our rope #8 was too good. However, the results are of interest because they were obtained with a range of five instruments, and five operators. We could, therefore, record comparative results from both a hardware and operator point of view.

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‡: it should be noted that even though the 'non-rotating' (NR) ropes are spin-resistant, they will rotate somewhat under certain conditions.

Keywords: New Brunswick; Mineral Development Agreement; Wire-ropes; Non-destructive-testing; Electro-magnetic instruments; Hoist-ropes; Spin-resistant/Non-rotating ropes

EDM CANADA/N.-B. - PROJET VISANT L'ESSAI DE CÂBLE DE PUITS DE MINE; ESSAI D'UN CÂBLE ANTI-GIRATOIRE DE 1 5/8, 18 X 7 (NOTRE CÂBLE #8)

par

L.B. Geller*, D. Poffenroth}, J.E. Udd** et D. Hutchinson}}

RÉSUMÉ

Les auteurs analysent les résultats d'essais non destructifs effectués sur un câble anti-giratoire , résistant à la rotation, 18 x 7, de 1 5/8 de pouce de diamètre. Le câble a été examiné sur toute sa longueur dans le cadre du projet de CANMET visant à faire une évaluation comparative d'une gamme d'appareils d'essai électromagnétiques de câbles métalliques. Toutefois, les auteurs disposaient des résultats d'essais antérieurs réalisés sur place. C'est la première fois que l'on a entrepris un projet de cette envergure, portant sur autant d'appareils.

Les essais ont été réalisés au moyen des appareils suivants : Magnograph (canadien), Rotesco AC, Rotescograph, LMA-250 (américain) et WBK (allemand). La perte de résistance maximale est considérée comme négligeable par l'opérateur de l'appareil Rotescograph, et est évaluée à 2,9 % par l'opérateur de l'appareil Magnograph. Les opérateurs des appareils américain et allemand n'ont pas fourni une estimation de la perte de résistance maximale.

Le projet de CANMET avait pour objet de mettre à l'essai des câbles en mauvaise ou très mauvaise condition. Dans ce contexte, la condition du câble #8 était trop bonne. Toutefois, les résultats sont d'un certain intérêt, car ils ont été obtenus par cinq opérateurs au moyen de cinq appareils. Il serait donc possible de comparer les résultats des points de vue de l'équipement technique et des opérateurs.

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Bien que les câbles anti-giratoires soient résistants à la rotation, un certain mouvement de rotation peut se produire dans certaines conditions.

Mots clés : câbles anti-giratoires/résistants à la rotation; appareils électromagnétiques; câbles de levage; câbles métalliques; entente sur le développement minéral; essai non destructif; Nouveau-Brunswick

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BACKGROUND

The results described in this report constitute an integral part of the contracted phase of CANMET's project, undertaken in 1986 in response to requests by both the mining industry and the mine regulatory authorities. The basic project objectives specified that the continuing rope failures, or near failures — occurring despite mandatory wire-rope examinations with electro-magnetic (EM) instruments at regular intervals — be examined, documented, analysed, and the reasons for these occurrences clarified. This is the first time a project of this scope and depth has been undertaken, anywhere.

CANMET's work included both in-house and contracted work phases. The in-house phase resulted in a range of conclusions and recommendations, reported elsewhere (references 1 through 6). We are now in the process of reporting the results obtained during the contracted project-phase, which included an extensive series of both in-situ and shop-floor tests. The first sixteen reports to describe this project phase were prepared in the period February, 1990, through May, 1991 (references 7 through 22). More are to follow.

ROPE DETAILS

The rope of current interest (referred to as "our rope #8") was designated #1 Tail Rope in Shaft #2, compartments 1 and 3 (skips #1 and #3) of International Nickel Company of Canada's (INCO) Shebandowan mine at Shebandowan, Ontario. It was manufactured by Wire Rope Industries Ltd. of Pointe Claire, Quebec. Its reel number was 020991. It measured $1\frac{5}{8}$ in. diameter × 2,651 ft. It was of an 18×7, NR**, construction (outers: 6×.111; centre: 1×.118 in.), with a mass of 4.80 lb/ft; right Langs lay; nylon core. Its breaking strength was 222,450 lb (see Ontario MOL test #57469). It was installed on 1981 02 06*, and removed on 1988 09 05, i.e., it was in use for 7 years and 7 months. However, while the rope was in-situ all this time, and tested at regular four monthly intervals, the mine was shut-down from 1985 through 1988.

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*: dates are given in this order: year, month, day

**: it should be noted that even though the 'non-rotating' (NR) ropes are spin-resistant, they will rotate somewhat under certain conditions

IN-SITU TEST RESULTS — AS REPORTED AND REVIEWED

The Rotesco AC data

In-situ test results were obtained by INCO staff with a Rotesco AC instrument on a routine regulatory basis. Specifically, EM tests were performed on: 1982 01 15; 1982 10 27; 1983 06 24; 1984 03 02; 1984 10 26; 1985 08 16; 1986 03 13; 1986 09 30; 1987 09 24; and 1988 05 26. The LBS_{max} estimates indicated: (a) no loss from January, 1982, to March, 1984, (b) a 1.5% loss from October, 1984, to March, 1986, (c) a 2.0% loss on 1986 09 30, and (d) a 4.0% loss on the last two test occasions. The LBS_{max} was reported either some 870 ft to 1,000 ft from the #3 skip, or some 50 ft to 100 ft from the #1 skip.

The last in-situ test before rope removal was test #SH-376, on 1988 05 26. A copy of the relevant strip-chart is reproduced in Fig. 1a. The operator reported a loss of breaking strength (LBS) of 4.0% at 870 ft from start of the test at the #3 skip rope-end. Since for this rope-size the usual %LMA (loss-of-metallic cross-sectional area) to %LBS conversion factor for the Rotesco AC instrument is 1.6, the reported 4.0% LBS would indicate a 2.5% LMA at the given rope location. We could not detect such an LMA along the approximately 2,370 ft of tested rope-length. Our maximum %LMA (LMA_{max}) chart-reading was 1.4% some 25 ft from start of the test at skip #3 (Fig. 1a). The 0.0% LMA was approximately 1,970 ft from test-start. We cannot explain the reason for the discrepancy between the operator's reported LMA_{max}, and our own chart-reading.

SHOP-FLOOR TEST RESULTS — AS REPORTED AND REVIEWED

General procedure

The shop-floor tests were undertaken, reel-to-reel, with a Rotesco AC, a Rotesco-graph, a Magnograph, and an LMA-250 instrument, as well as with the prototype version of the latest German WBK tester. None of the operators knew about each other's results before these were submitted to us. All details of the testing process were described, and illustrated, elsewhere (7).

Rather than the full 2,370 ft rope-length that was tested in-situ, only some 380 ft (i.e., a fraction of the total length) were available for shop-floor testing. Unfortunately, we were not told from which part of the in-situ rope this length was cut, other than that it was from the "loop area". Nor could we detect any characteristic rope-defects

that might have answered this question unequivocally. The only reasonable assumption we could make was that the 'kink' noted in the shop-floor sample might be from the somewhat poorer rope-segment in Fig. 1a. This suggests that our rope #8 represents the first 370-380 ft of Fig. 1a.

In retrospect we believe that testing of rope #8 seems to have served little, if any, useful purpose.

The Rotesco AC data

The Rotesco AC data were obtained on a 370 ft rope-segment on 1989 04 03, a day before the permanent magnet instruments were used. This was done to ensure proper rope demagnetization. The shop-floor strip-chart is reproduced in Fig. 1b. Testing probably started at the #3 skip rope-end.

The seizing wire 'markers', on a 250 ft spacing, did not show up well, and were not identified by the operator on the strip-chart. Instead the chart-anomalies caused, according to the operator, by unscheduled stops and starts were recorded. These are marked with the symbol 'ST'. In our opinion rope stops and starts, *per se*, should not cause these spikes, under normal circumstances. Could, perhaps, activation of the reel-winder's motor-controller have caused these anomalies?

The operator reported that no significant losses were present (Fig. 1b). Our review (Fig. 1c) indicated an LMA_{max} of 0.2% (with a corresponding LBS_{max} of 0.3%) — somewhat meaningless results, due: (a) to their small absolute value, (b) to our inability to accurately read the strip-chart values, in view of the slow chart-speed (hence overcrowded events) and the oscillating nature of the LMA chart-trace, and (c) because we could not establish the relative levels of the 100% reference positions in the in-situ and the shop-floor charts.

As was the case with the Rotesco AC charts in case of reference 21, we again noted the numerous spikes on both the LMA and the eddy-current chart-traces. The Rotesco AC instrument is known to be very sensitive to extraneous electrical interference. This might, perhaps, explain the presence of these spikes.

The Rotescograph data

The operator tested some 377 ft of rope on 1989 04 04 (Fig. 2) and some 372 ft on 1989 04 10. The 377 ft test started at the skip #3 rope end, and the 372 ft test at the skip #1 rope-end. The seizing wire 'markers', on a 250 ft spacing, showed up well in Fig. 2a. The operator identified them by writing 'Marker' on the chart. The location

of a rope-kink was also noted, some 95 ft from the skip #3 rope-end. No LMA chart-readings were recorded. We added the 100% reference level and the LMA_{max} value of 0.8% to Fig. 2a ourselves. It will be noted that the LMA-trace shifted by some 0.6% on passing over the rope-kink location, without subsequently reverting to its original level.

Strip-chart speed was some 1.5 mm/sec. The operator reported that "there was no metallic area loss, and no depreciation in the breaking strength of the rope" (report #ME0011RPN).

No report was submitted for the 1989 04 10 test. Nor was the strip-chart marked. We added the 100% reference level, and the LMA_{max} value of 0.4%, to Fig. 2b ourselves. In this case the strip-chart speed was 10 mm/sec. Testing started at the skip #1 rope-end. As was the situation with the 1989 04 04 test (Fig. 2a), the LMA-trace shifted on passing over the rope-kink location, without subsequently reverting to its original level. In fact, practically, all of the %LMA occurred at the rope-kink location.

In this context it is interesting to recall the authors' relevant comments elsewhere, about shifting of the 100% reference levels as rope-defects had passed through the EM testers (e.g., note Tables 2, 4, 6, and 8 of ref. 7).

The Magnograph data

The operator reported (report #89-286C) having tested, on 1989 04 04, a rope length of 384 ft (Fig. 3). The seizing wire markers, on a 250 ft spacing, showed up well. In Fig. 3 these are identified by the symbol 'Mk'. The rope-kink location at 102 ft from start of the test is also identified. Testing started at the skip #3 rope-end. An LMA_{max} of 0.5% was reported. Under these conditions the operator's LMA sensitivity choice of 0.5% per minor chart division seems inappropriate to us, especially since the operator had undertaken more than one test-run. Moreover, the test data had been recorded on tape. They could, therefore, have been submitted to us at a higher strip-chart recorder gain setting, and thus in a more accurately legible form.

The LBS_{max} was estimated to be 2.9% at 120 ft from start of the test. The operator also commented — presumably on the basis of prior personal experience with tail-ropes — that, due to work hardening effects, the 'true' breaking strength of this rope would, if measured, probably have been more than the original rope strength.

We agree with the reported data, *per se*.

The LMA-250 data

The operator reported having tested a rope length of some 381 ft (Fig. 4) on 1989 04 04. The seizing wire markers, on a 250 ft spacing, showed up well. In Fig. 4 these are identified by the symbols 'M1' and 'M2'. The rope-kink location, 90 ft from start of the test, is also marked. Testing started at the skip #3 rope-end. The 0.0% LMA reference level was placed here. An LMA_{max} of 0.4% was reported. No LBS estimates were submitted.

We agree with the reported data.

The WBK data

Shop-floor testing was performed on 1989 04 10 with the German WBK instrument — concurrently with the second Rotescograph test-run. The rope length tested was 397 ft (121 m). The strip-chart contains, reading from top-to-bottom: five LF traces, a %LMA trace, and a length indication scale (in meters). There is also space for a second %LMA trace and for a rope-diameter indication-trace (not used in the current test-series). With the sensor-head closed, the individual measuring coils LF #1 and LF#2 were joined together, and so were #3 and #4. The fifth LF chart-trace summarizes the output of these two individual traces. Surface defects, such as the seizing-wire markers, were particularly conspicuous on this instrument's LF and LMA traces.

The two WBK operators carefully annotated their chart, including some LMA readings, the kink location (at 105 ft from skip #3 rope-end), and the seizing-wire marker (M1 and M2) locations. They also submitted a report. Testing commenced at the skip #1 rope-end. There was an LMA difference of 1.5% between the two rope-ends.

We did not receive a copy of the complete strip-chart. Instead, copies of the important chart sections were submitted, numbered Figures 8.1 to 8.4, inclusive. We reproduce these as our Fig. 5. As may be seen, the 0.0% LMA reference level was set along the skip #3 rope-end; the %LMA scale was 0.248% per mm of full-scale diagram (see 'Fig. 8.1' of our Fig. 5). We added our own marking of the height of the %LMA chart-spike at the M1 seizing-wire marker. Test results are tabulated in Table 1.

The German report included a tabulation of the M1 to M2 marker locations. It is interesting to note that the tabulated distance between these markers was 75 m (246.1 ft). The corresponding 'true' distance was 250 ft.

We agree with the operators' report.

DESTRUCTIVE TESTING

The in-situ and reel-to-reel shop-floor tests of rope #8 did not indicate any deterioration of sufficient severity to warrant destructive testing of any of the rope segments.

ANALYSIS OF TEST RESULTS

(1) General comments

Considering the influence of the instrument calibration-procedures upon the test-results, we included relevant information about these matters in Table 1, such as: (a) the rope-end at which calibration was effected, (b) the rope-segment at which 0.0%LMA was found to be, and (c) the %LMA difference between the two rope-ends.

We added to all charts: (a) the 100% reference levels, (b) the relevant sensitivity scales (%LMA per major chart-division), and (c) the LMA_{max} chart-readings. It should be noted that our rope #8 represented only a fraction of the original, in-situ, rope-length. Moreover, its 0.0% LMA level was, in all likelihood, some 1.0% below the 0.0% LMA reference level of the in-situ rope.

The rope was in a relatively good condition. The major interest in examining it was the opportunity to compare test-results obtained with five different instruments, and operators. All told, though, there seems to have been little, if any, reason for examining rope #8 within the framework of CANMET's project. We did not find anything of particular interest to comment upon.

Details of the test set-ups are listed in Table 2.

(2) LMA chart readings

We tabulated the %LMA chart-readings in Table 1. We agree with the reported values, *per se*.

Comparative evaluation of the five EM instruments used can, perhaps, be best based on the LMA_{max} chart-readings (Table 1). However, these, as well as the %LMA chart-readings at the characteristic rope-anomalies — such as the rope-kink and the two rope-markers — were too small for accuracy, and to be meaningful. The markers consisted of $\frac{1}{16}$ in. diameter wire, wound around the $1\frac{5}{8}$ in. rope at 250 ft intervals along 2 in. stretches. Noting that the metallic cross-sectional area (A) of the rope itself was assumed to be 1.1335 in^2, addition of the seizing-wire 'markers' represented a metallic

area increase — i.e., LMA 'spike' — of some 22%. Due to the operator's sensitivity setting, the 'spikes' on the Magnograph chart-trace were not large enough to permit reasonably accurate scaling. We list the 'height' of these spikes in Table 1, with M1 being closest to the skip #3 rope-end.

In this context, though, we must also mention the physical instrument characteristic usually referred to as 'quantitative resolution'. As an example, for the Magnograph we noted (see Fig. 32c in ref. 7) that a 2.0 in. long rope-anomaly will only produce some 36% of the numerically correct reading on the instrument's LMA strip-chart. In the present case, therefore, only some 36% of 22%, or about 7.9%.

Apart from the one kink, this rope was in a relatively good condition, with the LMA_{max} not exceeding 1.5%. Under these conditions the Magnograph operator's LMA setting of 2.5% per major chart-division is inappropriately insensitive.

(3) LBS estimates

Since we did not perform any destructive rope testing, we had no way of checking the accuracy of the operators' LBS estimates. These were, in any case, too small to be of any practical interest.

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APPENDIX

Tables 1 and 2

as well as Figures 1 through 5, inclusive

Table 1

In-situ and shop-floor test-results

	In-situ	Shop-floor					
Subject	Rot. AC 1988 05 26 Fig. 1a	Rot. AC 1989 04 03 Fig. 1b	Magnogr. 1989 04 04 Fig. 3	LMA-250 1989 04 04 Fig. 4	Rotescogr. 1989 04 04 Fig. 2a	Rotescogr. 1989 04 10 Fig. 2b	WBK 1989 04 10 Fig. 5
tested rope length	2,370 ft	370 ft	384 ft	381 ft	377 ft	362 ft	397 ft
Max. %LMA: @ ft*	2.5%‡ 870 ft‡	0.2% 25 ft & 340 ft	0.5% 72 – 180 ft	0.4% 170 – 381 ft	0.8% 100 – 377 ft	0.4% 0 – 80 ft	1.5% 371 ft
0.0% LMA @:	1,970 ft††	mid-point	both ends	skip #3	skip #3	skip #1	skip #3
calib. @: #3 skip;	yes	yes	yes	yes	yes	—	—
#1 skip;	—	—	—	—	—	yes	yes
%LMA diff. betw. ends:	0.6%	0.1%	0.0%	0.4%	0.8%	0.0%	1.5%
%LMA chart-read & (spike-height) @:							
M_1†	—	—	0.0%;(?)•	0.0%;(0.9%)	0.0%;(0.4%)	0.6%;(0.4%)	0.0%;(2.0%)
M_2	—	—	0.5%;(?)	0.3%;(0.4%)	0.8%;(0.6%)	0.2%;(0.7%)	—
kink	—	—	0.5%;(0.5%)	0.4%;(0.4%)	0.4%;(0.4%)	0.5%;(0.9%)	0.0%;(0.6%)

‡: as reported, vs authors' chart-reading of 1.4% LMA_{max} at 25 ft

††: as reviewed by authors; operator-choice was not reported

*: from the #3 skip rope-end

†: closest to the #3 skip rope-end

•: Magnograph readings too small for accuracy; but clear LF perturbations

Table 2

Details of EM testing of the $1\frac{5}{8}$ in., 18×7, NR, T.R.

Item No.	Test Instr.	Test No.	Test date	Test location	Instr. operator*	Test chart: Fig. #
1	Rotesco AC	#SII-376	1988 05 26	in-situ	(4)	1a
2	Rotesco AC	3	1989 04 03	shop-floor	(4)	1b
3	Magnograph	#89-286C	1989 04 04	shop-floor	(2)	3
4	LMA-250	—	1989 04 04	shop-floor	(5)	4
5	Rotescograph	ME-0011RPN	1989 04 04	shop-floor	(6)	2a
6	Rotescograph	—	1989 04 10	shop-floor	(6)	2b
7	WBK	—	1989 04 10	shop-floor	(7)	5

*: (7): instr. designer/maker and service company

(2) service company

(4) and (6): mining company

(5) government organization

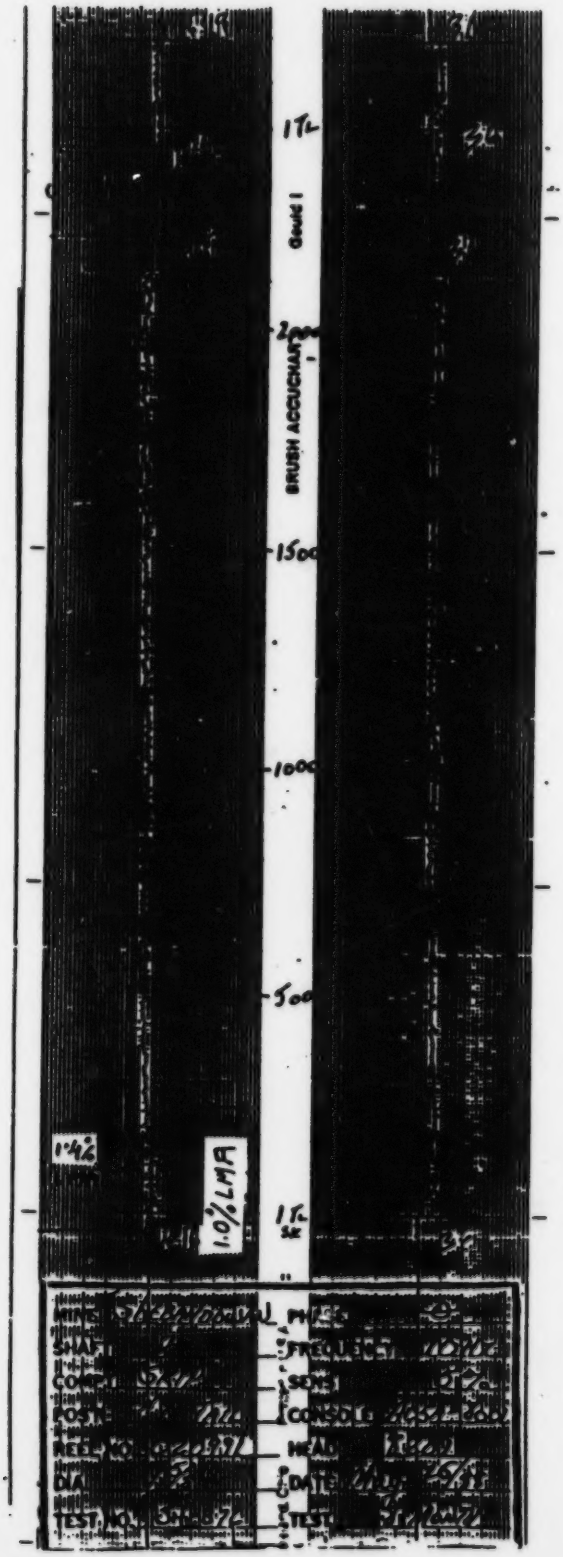
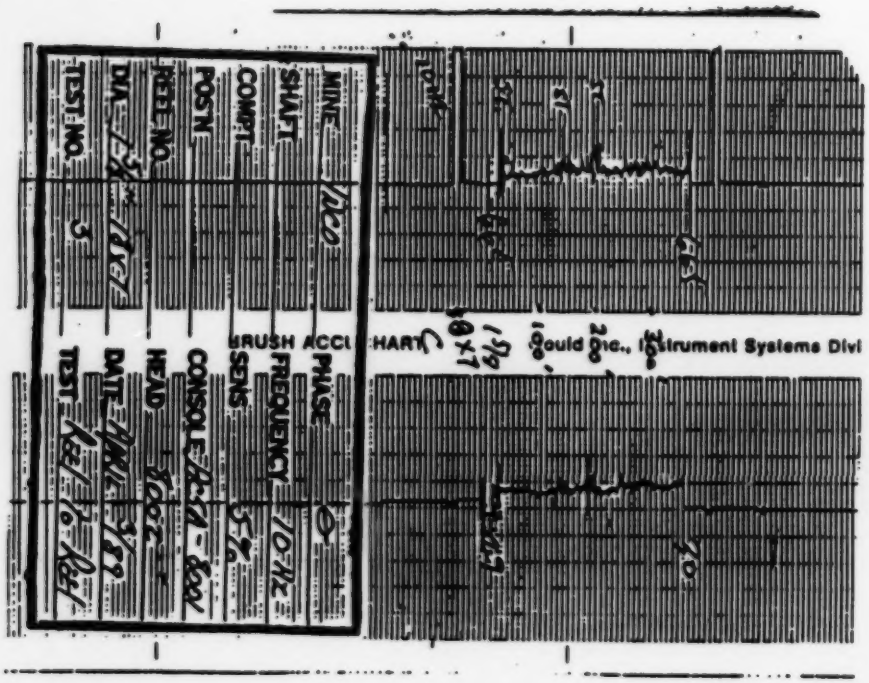
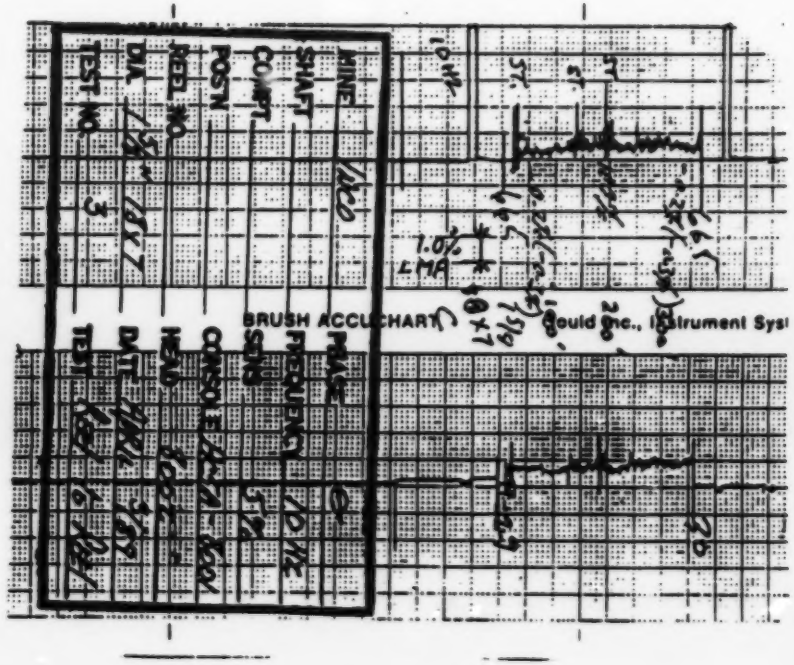


Fig. 1 — Rotasco AC test: (a) in-situ, of 1988 05 26



(b) shop-floor, as reported



(c) shop-floor, as reviewed

Fig. 1 (continued) — Rotesco AC test, of 1989 04 03

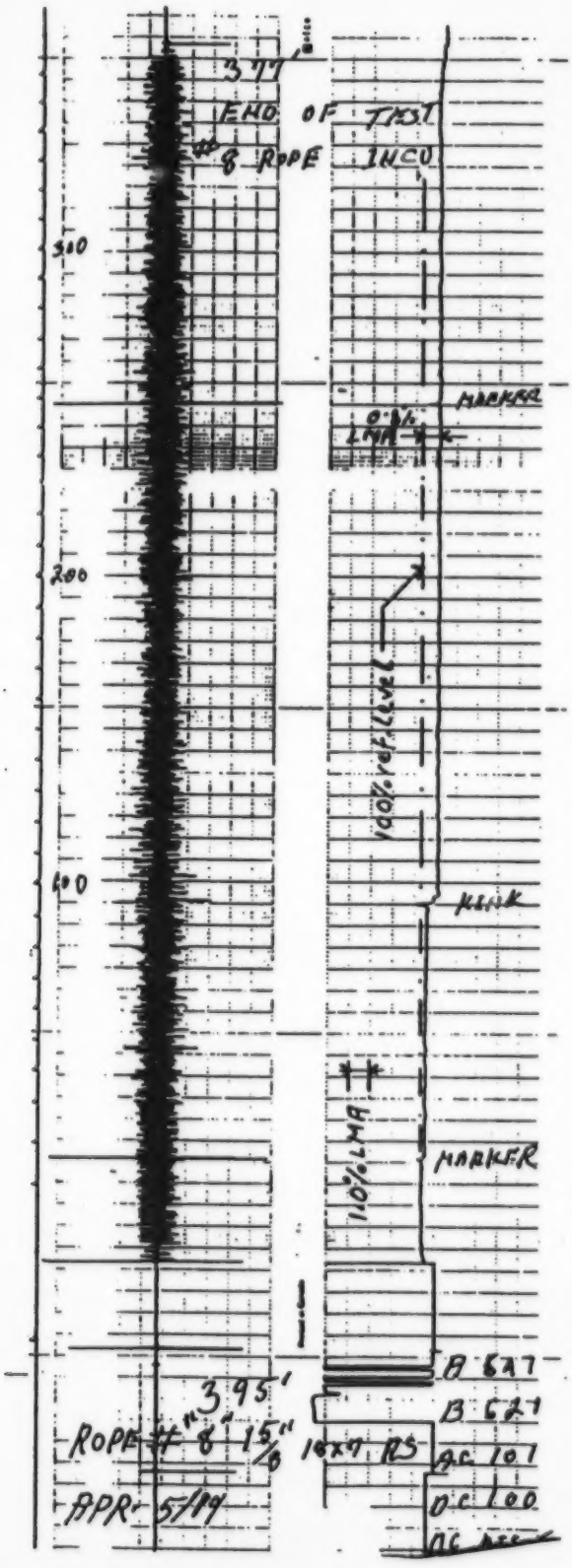


Fig. 2a — Rotescograph test, shop-floor, of 1989 04 04

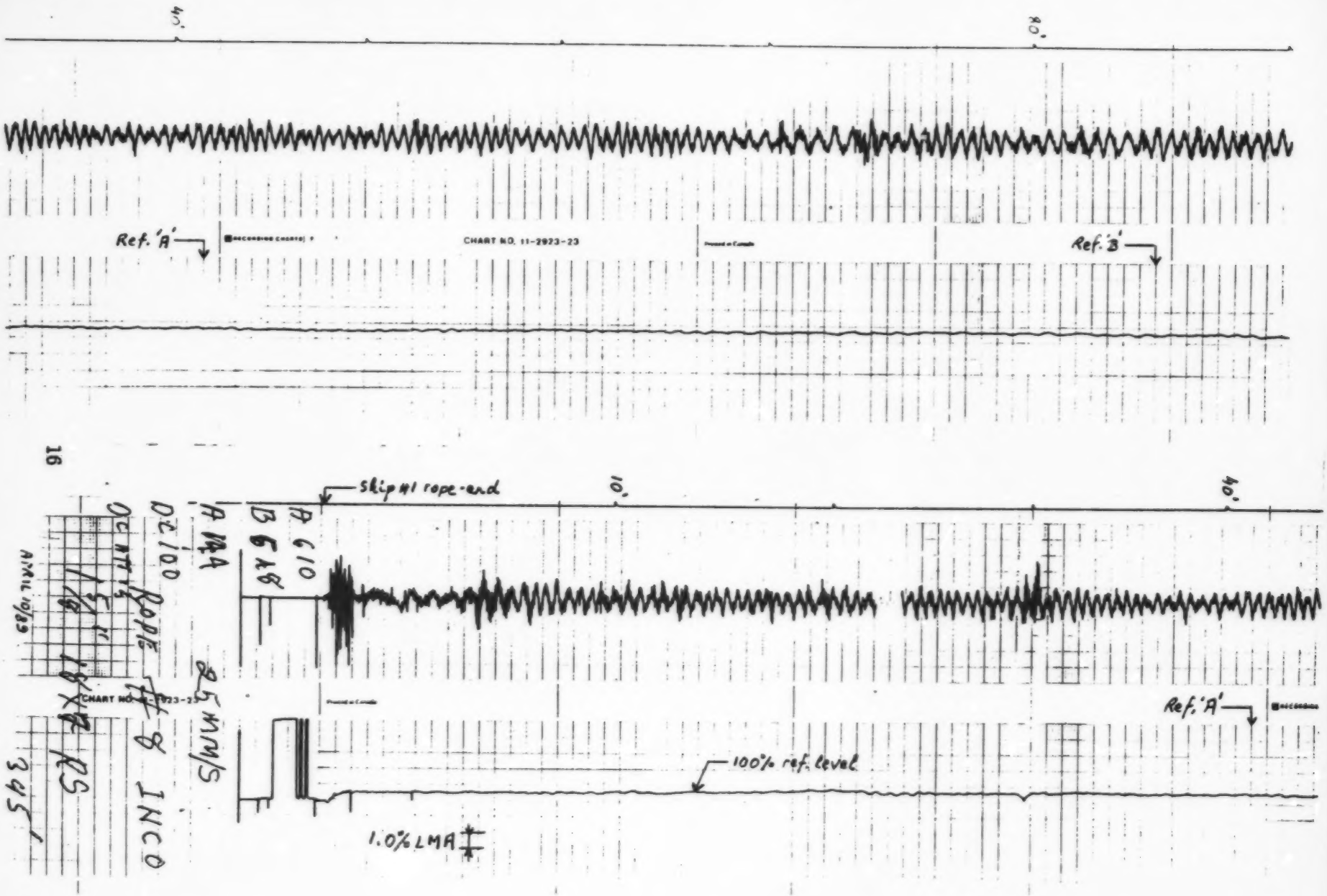


Fig. 2b — Rotescograph test, shop-floor, of 1989 04 10

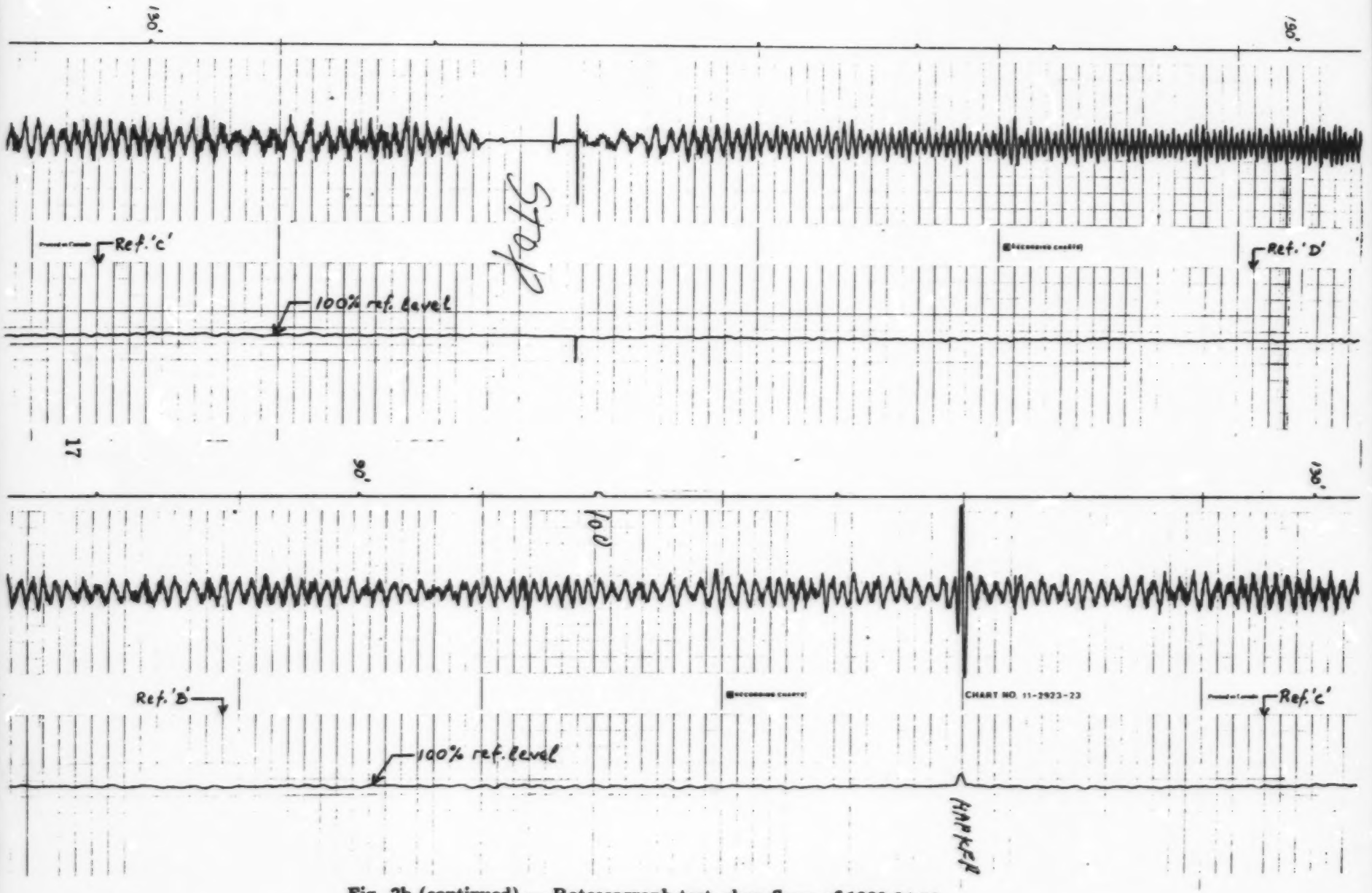


Fig. 2b (continued) — Rotescograph test, shop-floor, of 1989 04 10

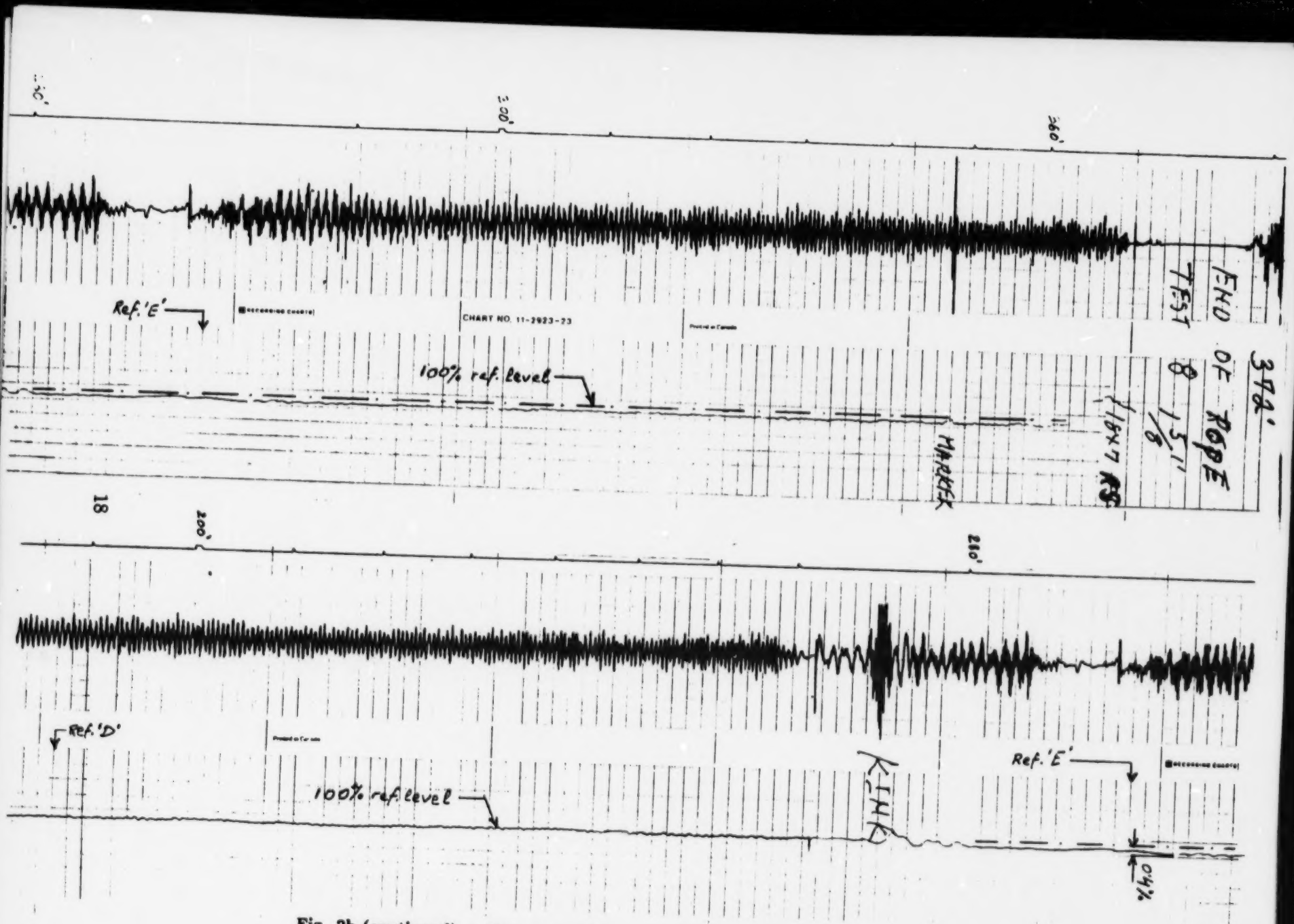


Fig. 2b (continued) — Rotescograph test, shop-floor, of 1989 04 10

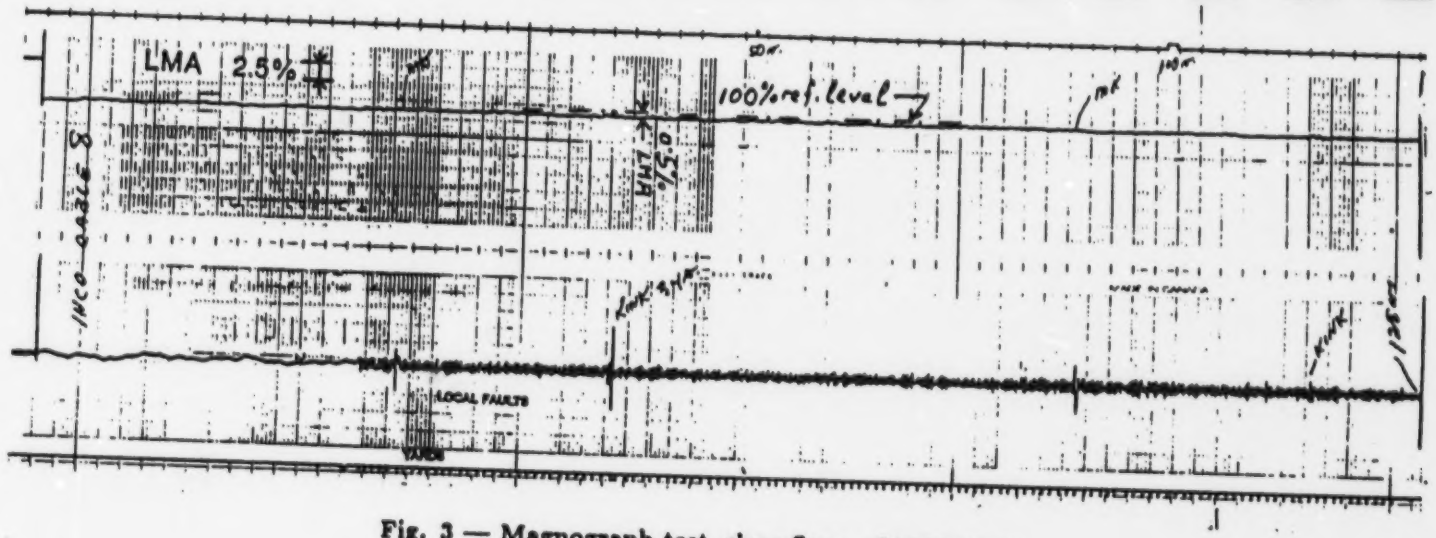


Fig. 3 — Magnograph test, shop-floor, of 1989 04 04

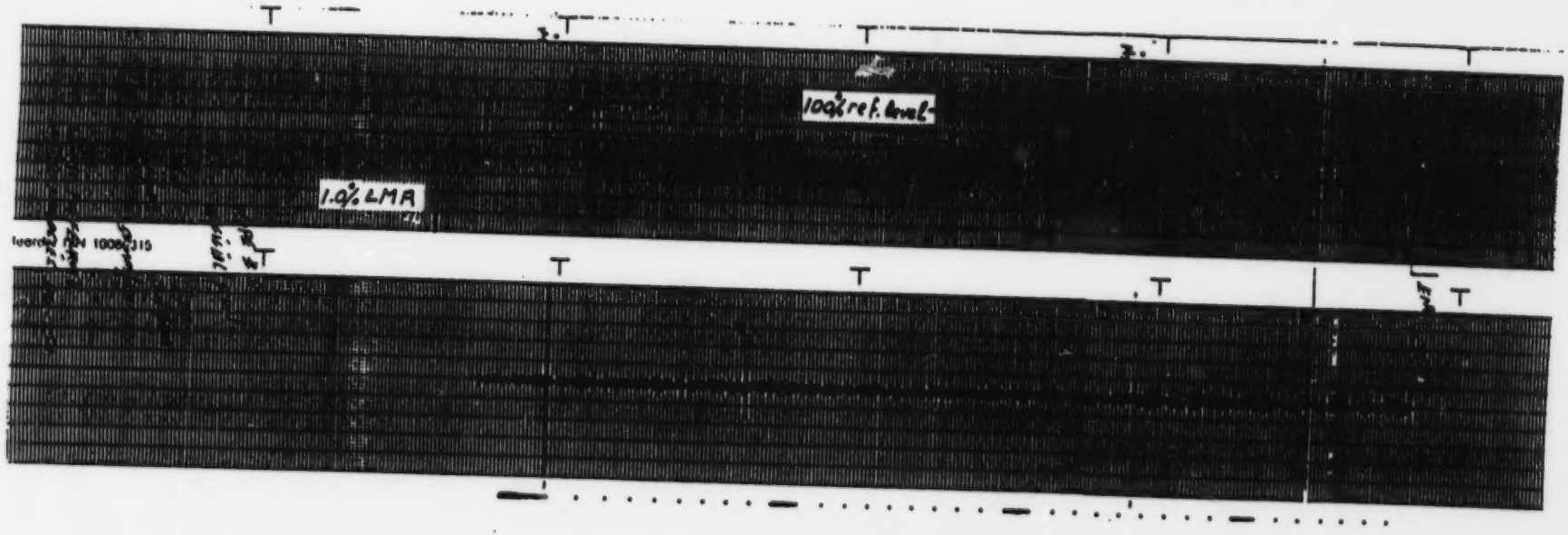


Fig. 4 — LMA-250 test, shop-floor, of 1989 04 04

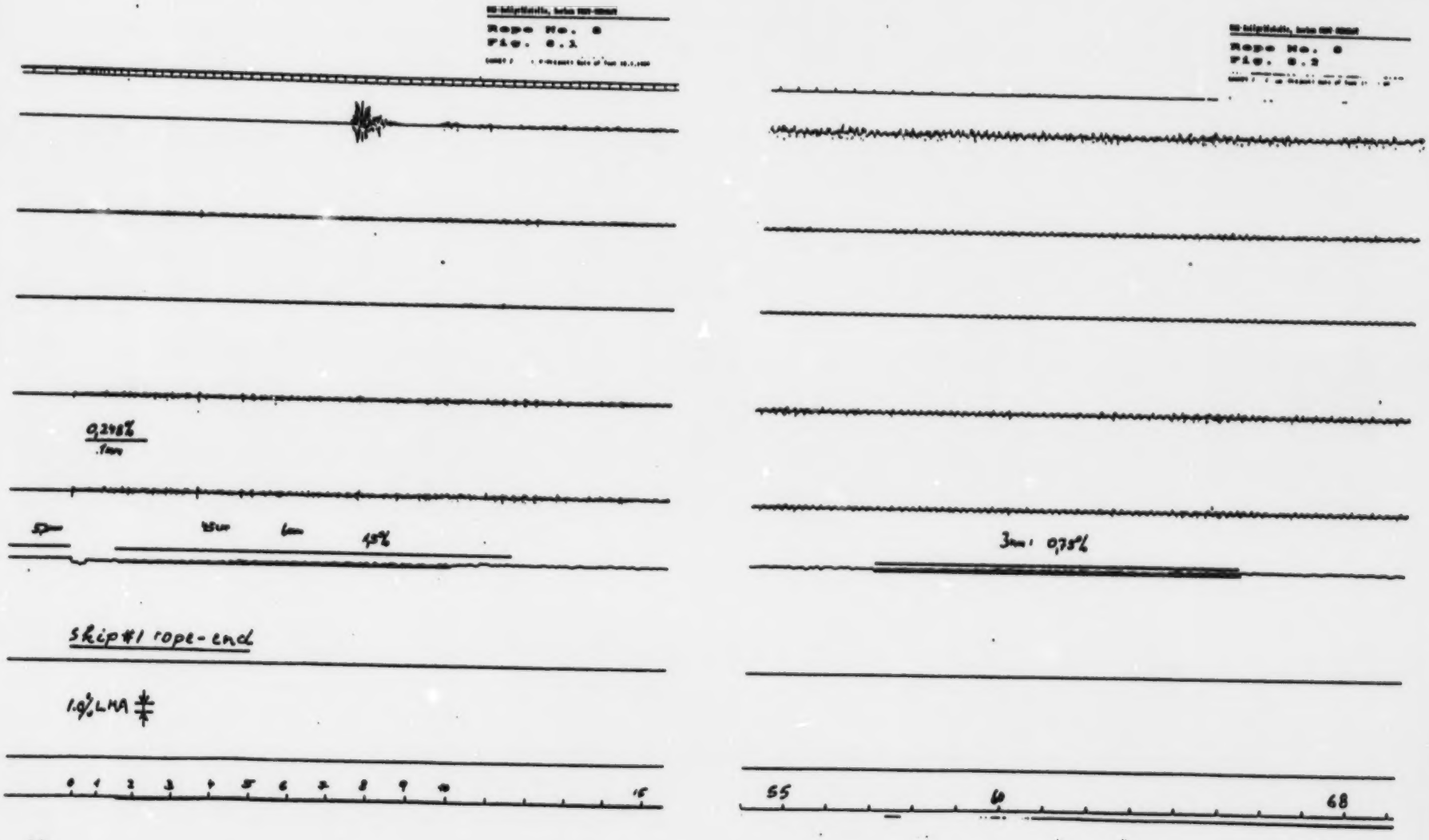


Fig. 5 — WBK test, shop-floor, of 1989 04 10

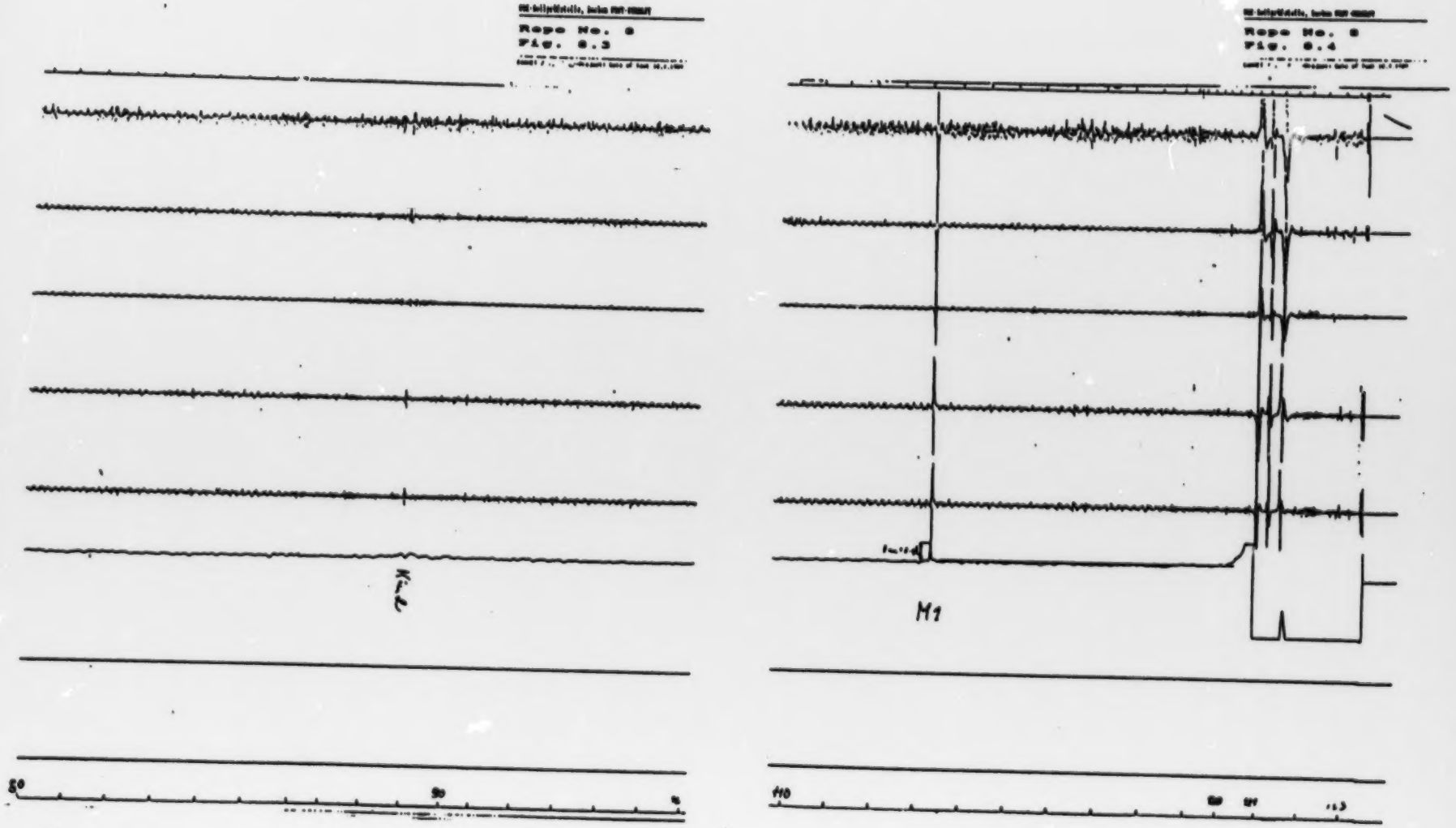


Fig. 5 (continued) — WBK test, shop-floor, of 1989 04 10